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INTERIM PROGRESS REPORT

AR ACTIVITIES

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INTRODUCTION

This report covers current activities to date on the Contractor's measurement and analysis program on AR materials and devices, especially in the fields of ferrimagnetics and configurations applicable to BEIGE's vehicle and its reduced profile requirements. An attempt will be made to issue subsequent reports on a monthly basis so that the Contracting Agency can be kept informed on program and material development progress, and findings can be included in Area studies and decisions with a minimum of time delay. The advice of Dr. Rodgers has been sought as much as possible on program direction and scope.

APPARATUS AND TEST PROCEDURE

The apparatus used on this program is shown in Figure 1. The electronic part of the equipment consists of an S-band generator, which introduces a signal into one arm of a hybrid Tee and irradiates the test piece with microwave energy. One arm of the Tee has an adjustable termination to eliminate a return to the fourth arm when a test piece is not in place.

The basic test specimens are aluminum panels, 2 feet square, coated with magnetic material and suspended by wires, as shown in Figure 1. An electric motor and a reducing gear system rotates the specimen at about one revolution per minute. A potentiometer is mounted on the drive mechanism and provides a DC signal proportional to the angular displacement, which is fed to the X-axis of an X-Y recorder. The Y-axis is fed with a signal proportional to the logarithm of the reflected power.

The design of the test procedure was largely influenced by Dr. Frank Rodgers. By means of a styrofoam mounting, a reflector is affixed to the specimen in the position illustrated in Figure 2. The basic test consists of measuring the reflection from the rotating assembly, with and without a metal foil covering the coated side of the panel. Attenuation introduced by the coating is taken as a figure of merit for the coating. Typical curves are shown in Figures 3a and 3b, which also illustrate the angular positions of interest.

The oven used to heat the panel for temperature testing may be seen in the background of Figure 1. In operation, this oven is moved forward to enclose and heat the test specimen to a temperature in excess of 600°F, whereupon the unit is quickly pulled away and reflection measurements made.

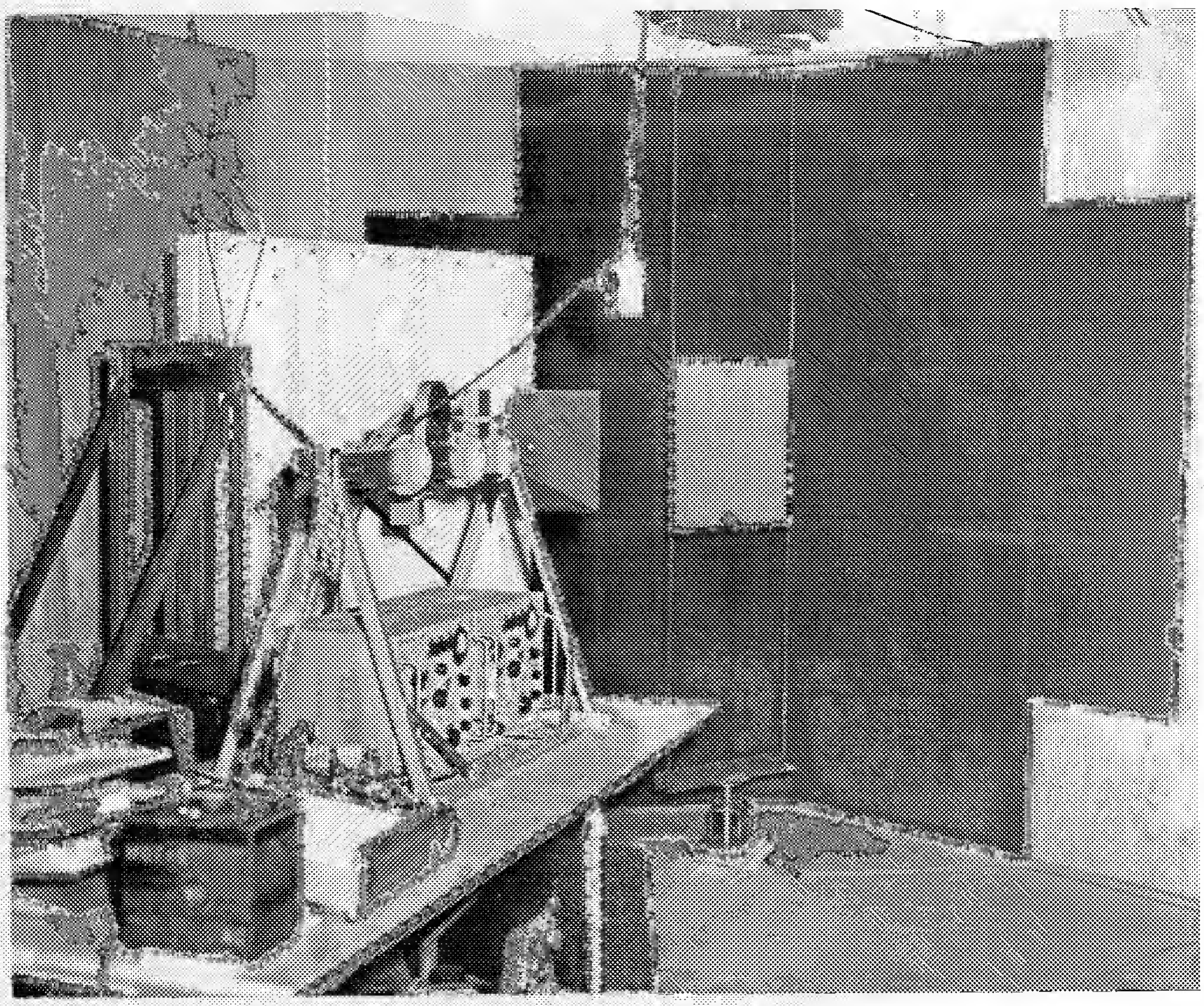


Figure 1. Test Apparatus

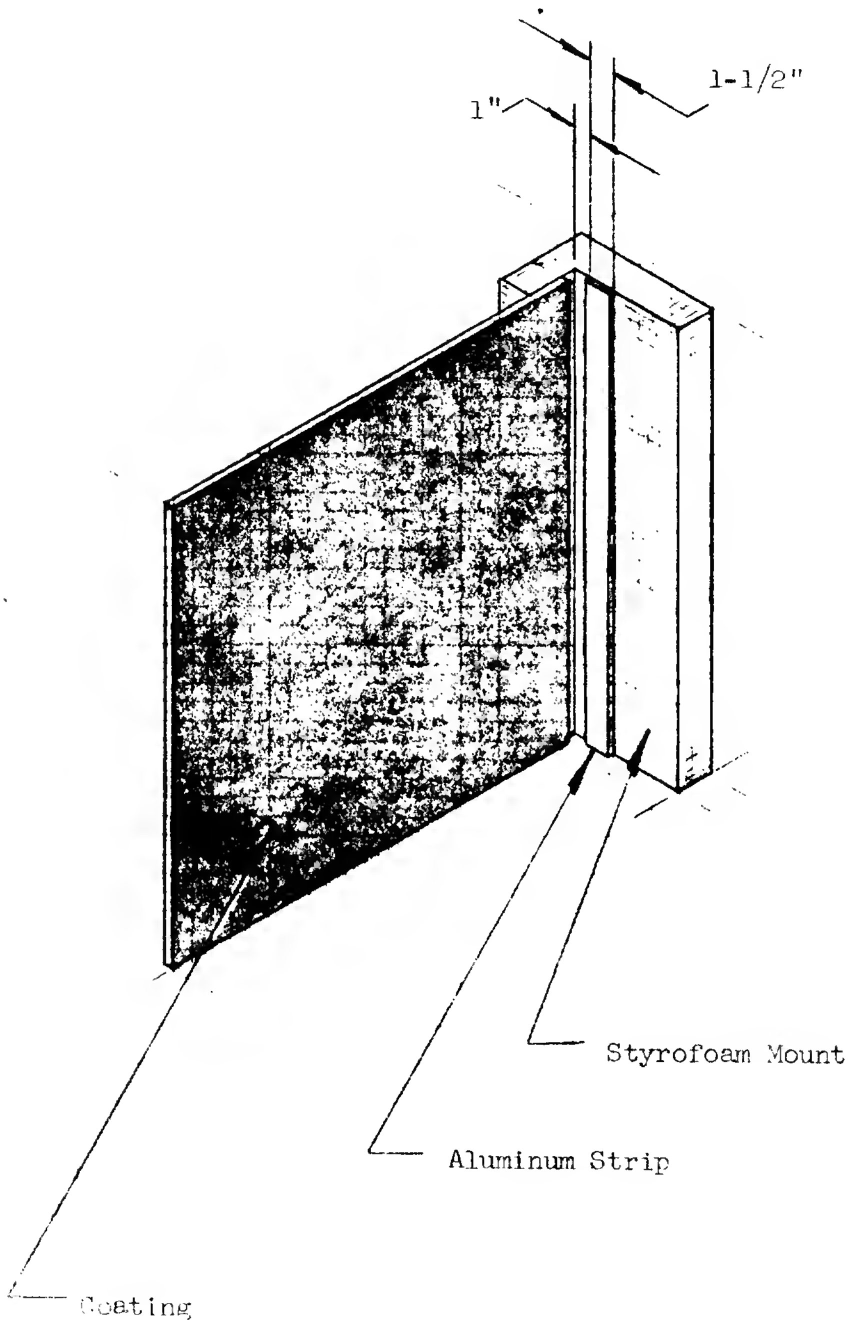
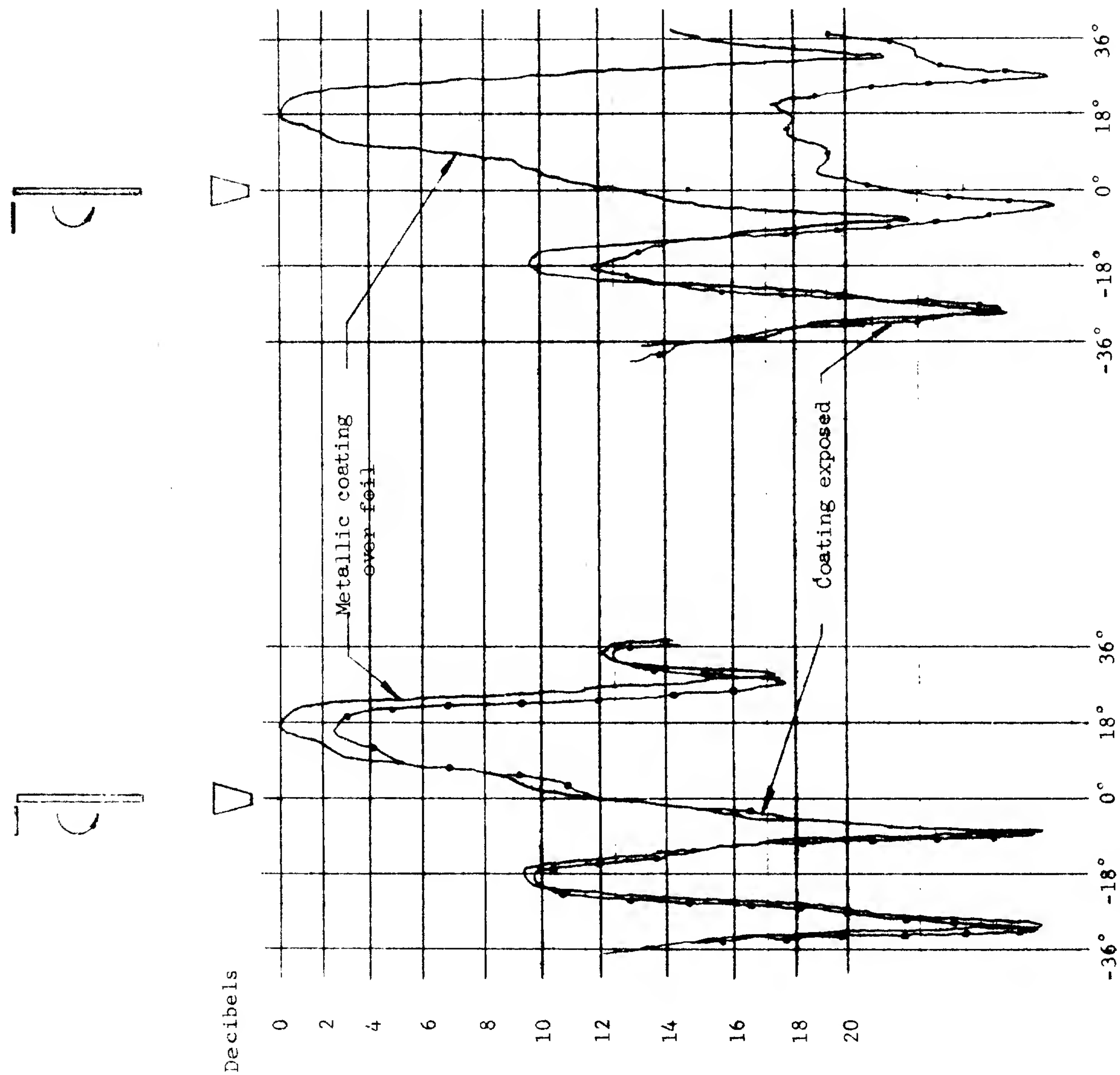


Figure 2. Mounting Detail



2N1 Before Cure

Figure 3a

2N1 After Curing 1 Hour @ 450°F
Measured at Room Temperature

Figure 3b

TEST RESULTS ON COATINGS NOT SUBJECTED TO HIGH TEMPERATURE

The basic materials involved in these studies are the simulated ferrimagnetic compositions described in the Invention Disclosure, "Suppression of Non-Specular Reflection," dated 6 October 1961 and transmitted to the Agency by our memorandum DTEM-1217 of 16 October 1961.

Table I summarizes test results and other properties of coatings fabricated to date, with the characteristics of various binder systems given in Table II.

The most significant parameter for collating this data would appear to be the surface density of iron; that is, the volume of metallic iron per unit area of surface. Figure 4 is a plot, therefore, of this parameter versus attenuation.

Coatings 6A1 and 2A2, which had previously shown the most stable electrical and mechanical properties, were applied in various thicknesses as a calibration. The resulting straight line on the chart was determined by four such points. The points below the line are regarded as being within the normal error in measuring the surface density. The points above the curve are more significant. These points have a general tendency to be associated with greater porosity and show that there is much room for improvement in our present processing.

Table I Coating Data

Formula	Pigment Volume Concentration	Pigment Particle Size,	Binder	Coating Thickness	Density	% Iron	% Porosity	Decibels Uncured	Decibels Cured
2N1	65	3	100% Silicone Resin	.030	4.9	58	11.0	16.5	2.5
2A2	70	3		.031	5.8	68	1.9	14.6	-
2A2-1	70	3		.022	-	68	1.9	9.0	-
2F1	56	*3, 10, 20		.021	5.07	58	0.0	5.8	4.2
2H1	56	25% - 3 8% - 10 67% - 20		.025	3.50	40	29.0	7.5	4.1
2K1	56	3		.017	4.65	53	5.0	7.3	-
2M1	75	3		.023	5.53	66	8.0	13.2	-
6A1	65	*3, 10, 20	Silicone Alkyd	.032	5.19	60	4.0	13.0	10.0
6A1-2	65	*3, 10, 20		.008	-	-	-	2.5	-
6C1	75	*3, 10, 20		.018	4.80	48	35.5	7.3	-
6F1	65	20		.026	3.84	44	27.0	7.0	-
6E1	65	3		.013	5.17	60	7.0	6.0	-
12A1	65	8 Insulated		.029	4.36	51	20.0	8.7	7.0
22A1	39	*3, 10, 20	Silicone Rubber (filled)	.039	3.96	39	0.0	9.0	7.0

Note: *Equal parts

Table II Binder Data

Number	Supplier	Resin Type	% Solids	Varnish Density	Resin Density	Recommend Cure
DC-805	Dow Corning Corp.	Silicone	50	1.01	1.19	1 hr @ 480°F
DC-804	Dow Corning Corp.	Silicone	60	1.05	1.24	1 hr @ 450°F
DC-996	Dow Corning Corp.	Silicone Alkyd	50	1.00	1.21	2 hrs @ 400°F
Q-2 0103-2	Dow Corning Corp.	Filled silicone rubber	100	-	1.52	2 hrs @ 75°F
V-204	Plaskon Div.	Phenolic	70	1.14	1.25	1 hr @ 275°F
R-65	Union Carbide Corp.	Silicone polyester	100	-	1.18	4 hrs @ 250°F

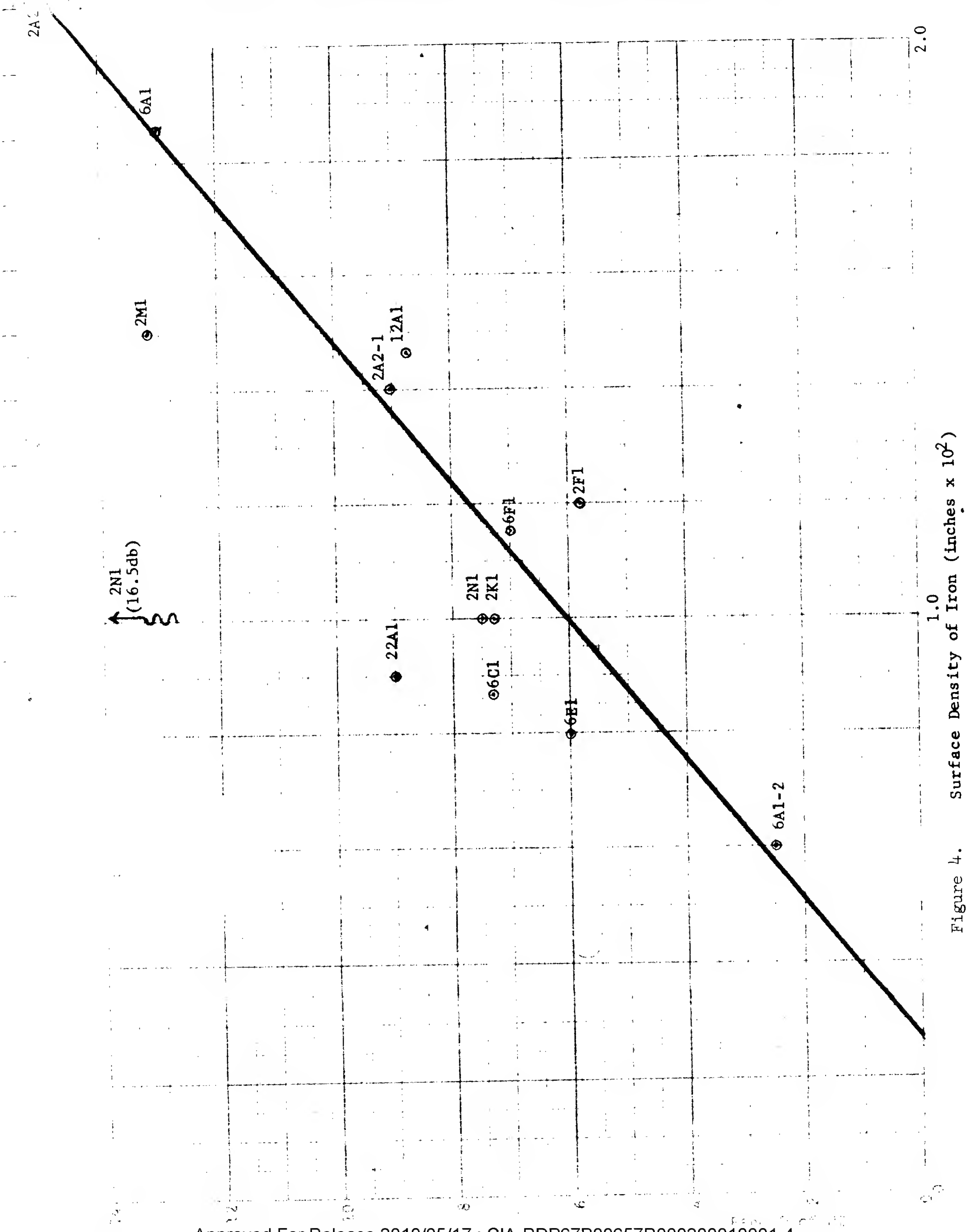

6A1
2M1
12A1
2A2-1
2F1
6F1
2N1
(16.5db)
2N1
2K1
22A1
6C1
6E1
6A1-2
2.0
1.0
12
10
8
6
4
2
Surface Density of Iron (inches x 10^2)

Figure 4.

EFFECTS OF TEMPERATURE

Two effects of temperature may be distinguished in our work to date. The first is a reversible effect, which is due to temperature variation alone and independent of the previous time-temperature history. The second is an irreversible effect, which is dependent on the time-temperature history. Present indications are that the latter are, by far, the most important.

A particularly impressive example of the irreversible effect is shown in Figure 3. Here, the most effective coating fabricated to date is rendered almost metallic by a short heat treatment at 450°F.

Some improvement was effected by top-coating the panels so as to fill up the pores. Although such panels did not deteriorate during a one hour cure at 450°F, a subsequent treatment for 16 hours at 550°F sufficed to virtually destroy their usefulness.

Two approaches to this problem have shown promise and will be intensively investigated in the future. First is the use of a silastic resin, and second is providing the iron particles with a "Pycerox" coating to render them chemically inert. It is encouraging that the silastic resin coating, 22A1, lies well above the straight line. Initial results of tests along these approaches are summarized in Table III.

Table III

Coating Description	Initial Attenuation	After 1 hr @ 450°F	After 16 hrs @ 550°F
Iron in silastic	9 db	7 db	6 db
Pycerox coated iron in 804 resin	10 db	10 db	

The reversible effects of temperatures are shown in Figure 5. There is about a 2 db change between 515°F and 90°F. Though this is significant, the irreversible effect is larger, as indicated by comparison of curves 1 and 4 in Figure 5.

RESEARCH ACTIVITIES

In addition to the development type activities previously discussed, a research program has been initiated to gain a better understanding of the electromagnetic phenomena involved in the operations of our coatings. Initially, these studies consisted of making field strength probes in the vicinity of coated plates with a 3/8" long antenna. The results of these studies were not definite and were difficult to interpret because of the many maxima and minima which occurred.

At this point, Dr. Frank Rodgers suggested the use of curved plates, with the objective of causing a surface wave which would not interfere with the space wave. Accordingly, 2' x 2' square aluminum panels were bent with a 4' radius and field strength measurements made on an uncoated panel in the orientation indicated in Figure 6.

This orientation is one that it would be instinctively believed to be the most adaptable to the launching of a surface wave. However, the field strength variation (as shown in Figure 6) showed the same large variations observed with flat plates.

It was thought that the launching of a surface wave would be accompanied by a low reflection from the curved plate. Accordingly, a reflection versus angle curve was determined, with the result shown in Figure 7a. An almost negligible

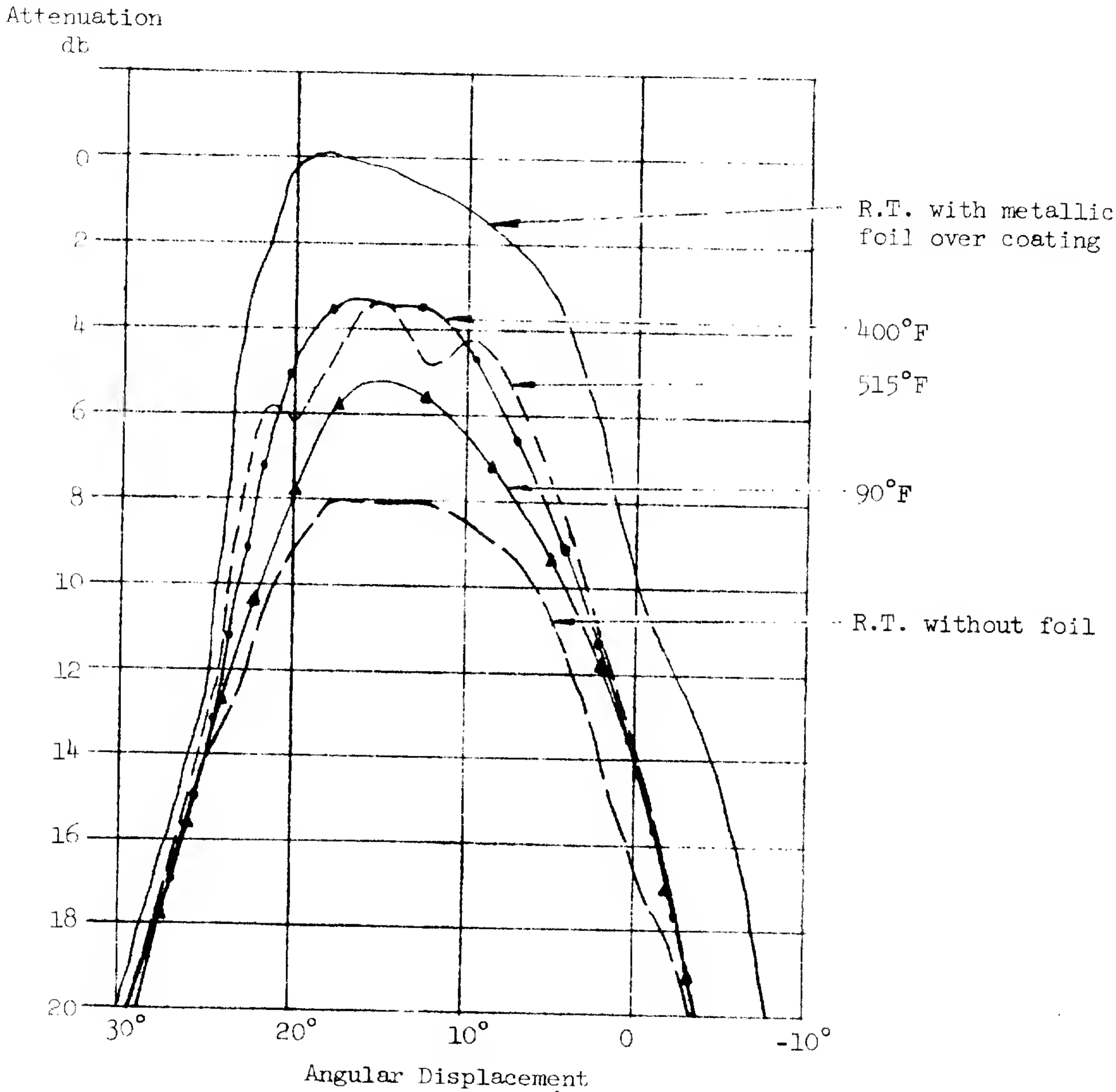


Figure 5. Effect of Temperature

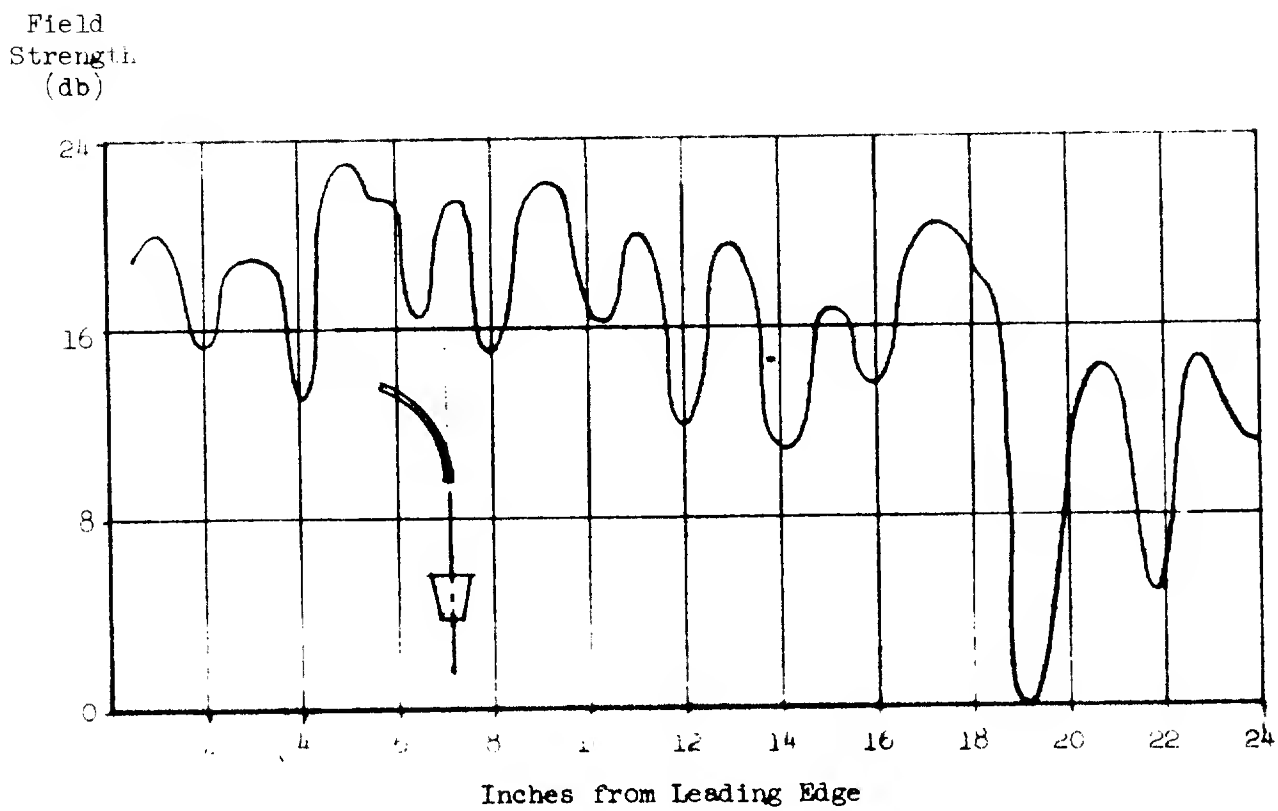
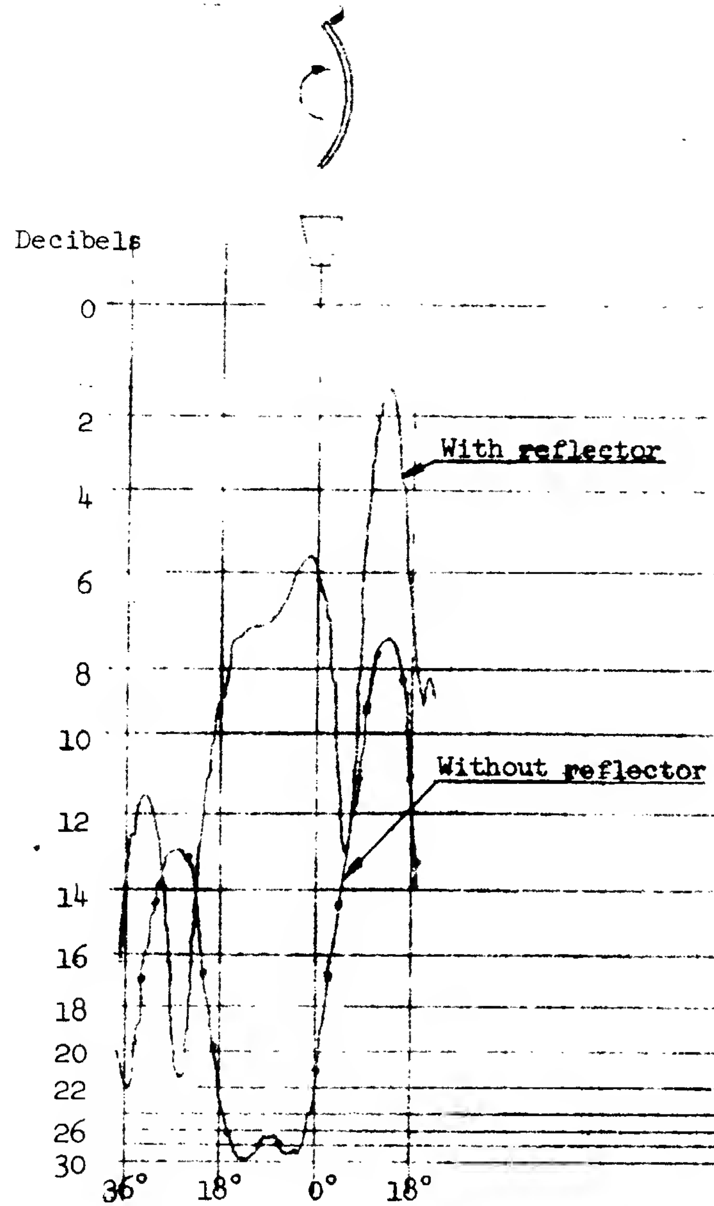
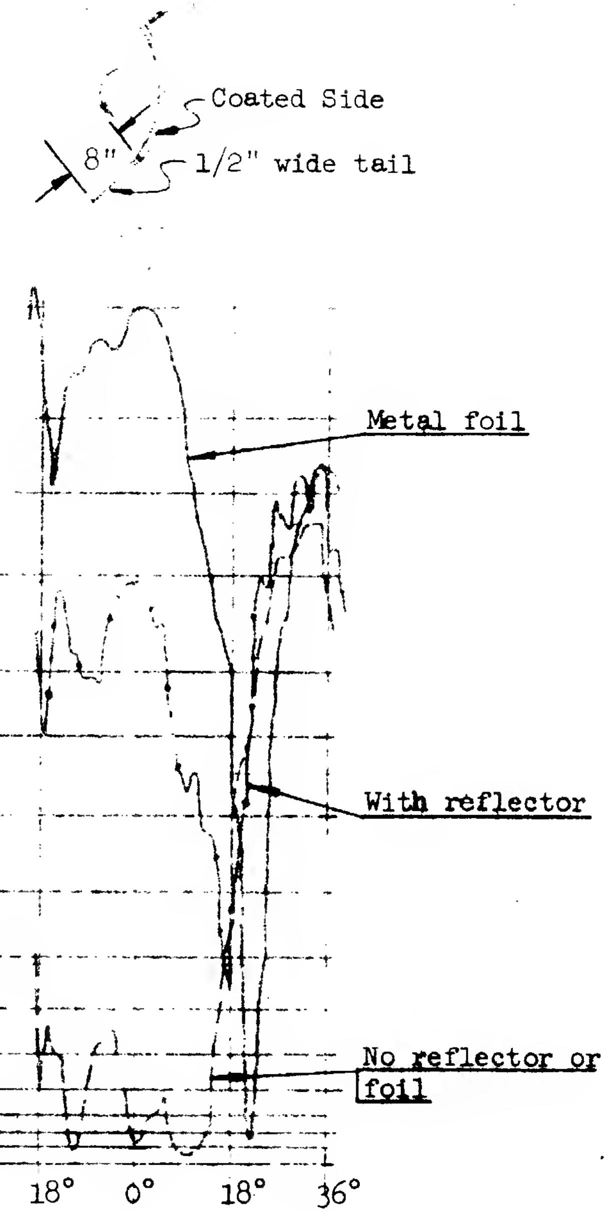


Figure 6. Normal Field on Convex Side of Curved Metallic Plate



Curved panel with no coating

Figure 7a.



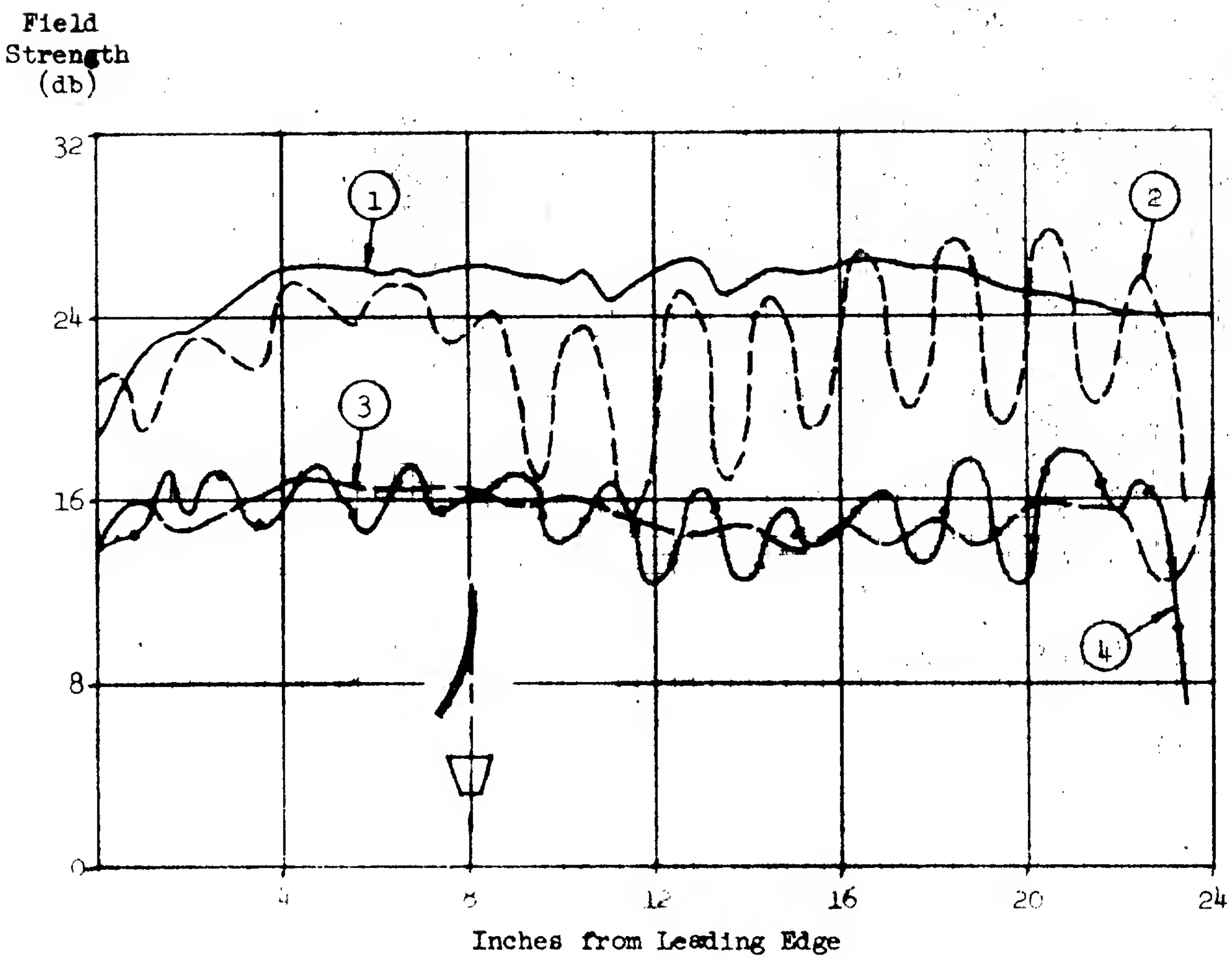
Curved panel 12/26 with tail 1-1/2" x 8" opposite reflector after turning

Figure 7b.

reflection occurred at an orientation exactly the opposite from that expected. This orientation is indicated in the inset of Figure 8 and corresponds to the trailing, rather than the leading, edge being parallel to the incident radiation. The reflectivity curve for the curved panel was also determined with a reflecting aluminum strip mounted as in Figure 2.

Comparison of Figure 7a with Figure 3 shows that the reflectivity curve with the reflector mounted is considerably flatter for the curved panel. This suggested the possibility of designing a more sensitive test with a curved panel. Accordingly, the convex side of the curved panel was coated and tests similar to those depicted in Figure 3 were made. The results of these tests are presented in Figure 7b. The fact that the comparitively flat regions for the curves in Figure 7b extend over a greater range than in Figure 7a is due to the addition of a "tail" in the position indicated in Figure 7b.

Field strength measurements like those for Figure 6 were subsequently made on the curved panel in the zero reflectivity orientation, with and without a coating. The results are presented as curves 1 and 3 in Figure 8. These curves are almost devoid of interferences as exhibited in Figure 6 and are completely consistent with the existence of a true surface wave. Additional field strength measurements, with the reflector mounted, are shown as curves 2 and 4 in Figure 8. The interference between the incident and reflected wave, as well as the attenuation of the latter in the presence of the coating, is clearly shown.



1. 20° from end on position with convex side toward horn, coating concealed by aluminum foil and without reflector.

2. Same as #1 but with reflector.

3. Same as #1 but with coating exposed.

4. Same as #3 but with reflector.

Figure 8.

The following remarks are intended to supply a crude understanding of these curved plate phenomena: First, assume the existence of a guided wave on the plate. This necessitates the existence of electric currents in the plate when it is not parallel to the direction of the incident radiation. In the case of Figure 6, these currents are largest at the trailing edge. Now, assume that these currents set up another wave which is guided along the plate. Then, interferences will be set up, as in Figure 6, and a substantial reflection will occur, as shown in Figure 7a. In the case of Figure 8, the largest currents are set up at the leading edge and the guided wave they generate is propagated in the same direction as the incident wave, so that interferences and reflections are absent.

The above argument is based on the assumption that currents at one end of the plate will set up a guided wave propagating toward the other end. The arrangement depicted in Figure 9 was utilized to test this assumption. Here, currents were introduced into the plate through a half wave length antenna fed by a coaxial cable so oriented as to cause negligible effects. The radiation of the whole structure was studied as a function of angle and the result is shown (on a logarithmic scale) in Figure 9. The results are in complete agreement with the above assumption.

Since it appeared that a true surface wave had been set up, it was felt that a field mapping experiment might yield significant results. A curved plate, with coating, was oriented for minimum reflection and the field explored in a domain which extended up to 8" normal to the coated side. The results are shown in Figure 10, in which the isopleths of constant illumination are plotted in 3 db steps. The regions are shaded to suggest the degree of illumination.

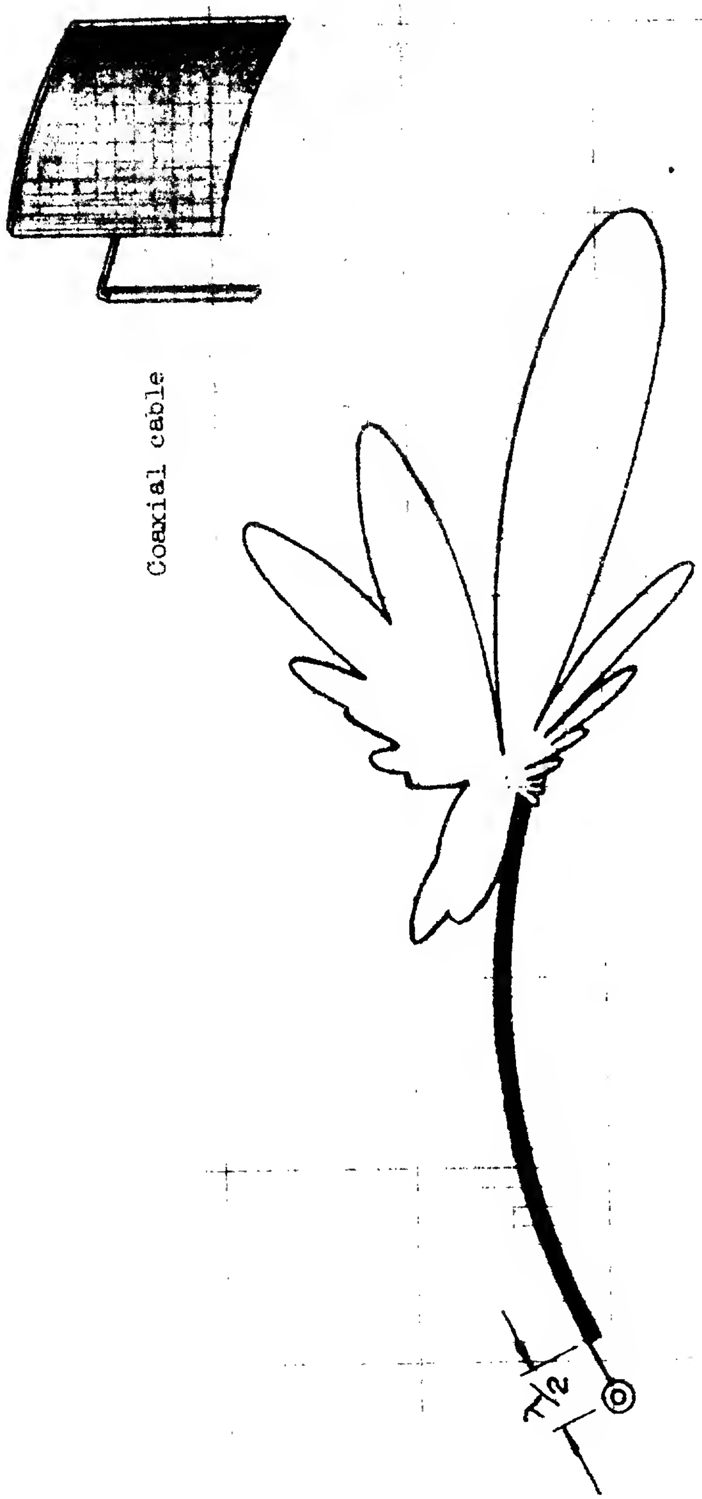


Figure 9. Radiation Pattern of Curved Plate used as Antenna

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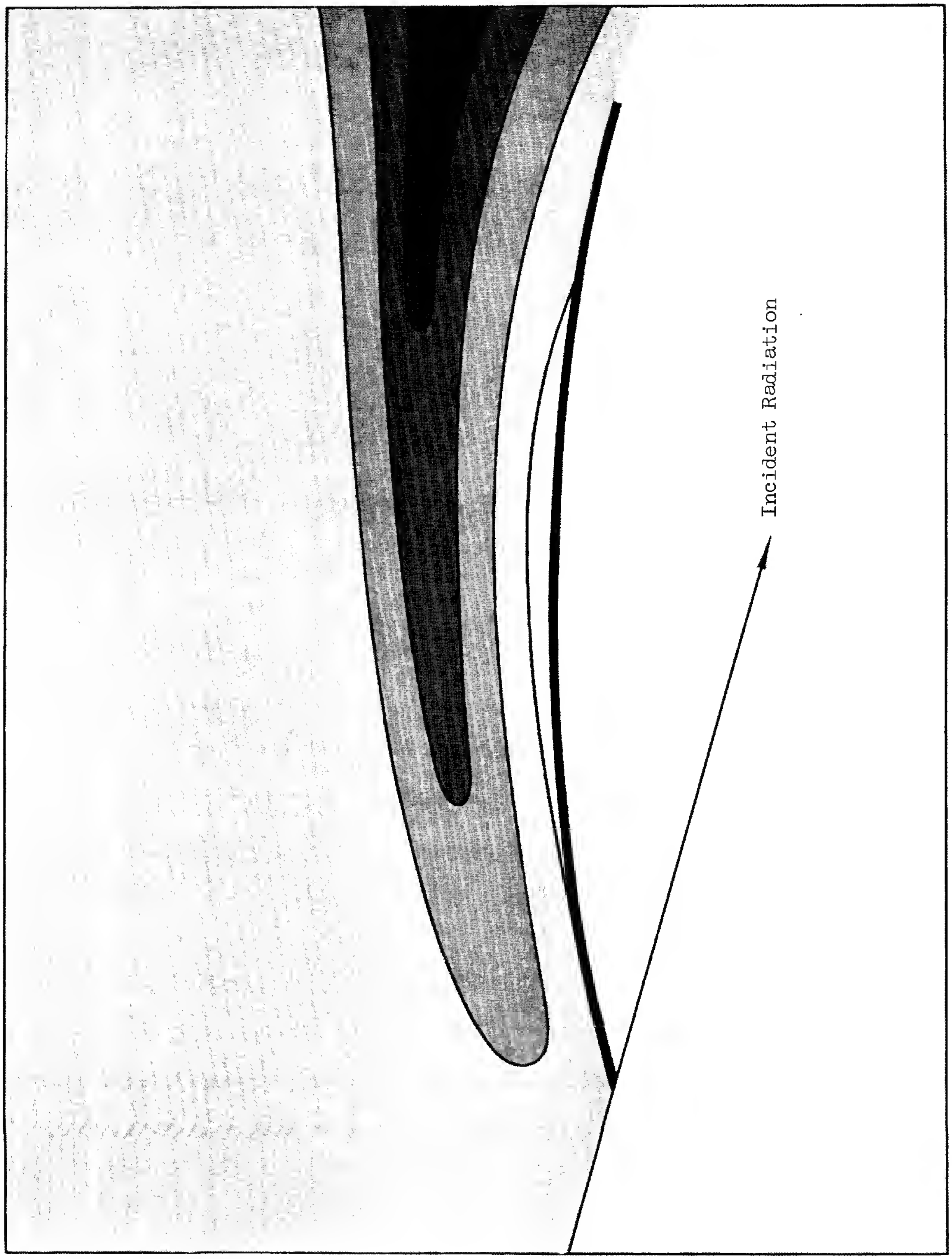

Figure 10. Field Plot on Convex Side of Curved Plate

The results are seen to be quite clear cut and it is planned to extend the field mapping experiments to the concave side of the plate and to investigate conditions when no coating is present.

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